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HIGH-FREQUENCY DE-ICING OF CABLEWAYS

RELATED APPLICATIONS

This application claims the benefit of US provisional application Serial No. 60/263,943, filed January 24, 2001, and of PCT application (serial number not yet assigned), entitled Ice Modification, Removal and Prevention, filed 22 January 2002. This application is also a continuation-in-part application of commonly-owned and copending US patent application Serial No. 09/426,685, filed October 25, 1999, which is a divisional application of US patent application Serial No. 09/094,779, filed June 15, 1998, issued as US Patent No. 6,027,075 on February 22, 2000. This application is also a continuation-in-part application of commonly-owned and copending PCT application PCT/US00/05665, filed 1 March 2000, which claimed the benefit of US provisional application Serial No. 60/122, 463, filed 1 March 1999, now abandoned, and provisional application Serial No. 60/131,082, filed 26 April 1999, now abandoned, and which is a continuation-in-part application of commonly-owned and copending PCT application PCT/US99/28330, filed 30 November 1999, which claims the benefit of US provisional application Serial No. 60/110, 440, filed December 1, 1998, now abandoned, the benefit of US provisional application Serial No. 60/122,463 filed March 1, 1999, now abandoned, and the benefit of US provisional application Serial No. 60/131,082 filed April 26, 1999, now abandoned. This application is also a continuation-in-part application of commonly-owned and copending PCT application PCT/US99/25124, filed 26 October 1999, which claims the benefit of US provisional application Serial No. 60/105,782, filed 27 October 1998, now abandoned. Each of the applications mentioned above is hereby incorporated by reference.

GOVERNMENT LICENSE RIGHTS

The U.S. Government has certain rights in this invention as provided for by the terms of Grant No. DAAH 04-95-1-0189, awarded by the Army Research Office, and of Grant No. MSS-

9302792, awarded by the National Science Foundation.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to methods, systems and structures for removing ice from surfaces, in particular, to deicing cableways, such as ski lift cables.

STATEMENT OF THE PROBLEM

The presence of ice on solid surfaces causes various types of problems. For example, excessive ice accumulation on aircraft wings endangers the plane and its passengers. Ice on ship hulls creates navigational difficulties, expenditure of additional power to navigate through water and ice, and unsafe conditions. Icing on power transmission lines adds weight to the power lines, causing power outages, resulting in millions of dollars of direct and indirect damage.

Problems associated with the formation and presence of ice on ski lift structures and other cableway systems are well known. Cableways, towers and related structures are exposed to wide ranges and varying conditions of temperature, humidity and precipitation that lead to the formation and buildup of ice. Ice interferes with smooth and efficient operation of cableway systems. Ice on cables and associated structures frequently causes expensive damage. More importantly, ice on cableways and towers poses safety risks. Ice and snow deposits on cables and coupling structures can cause system malfunctions while being used to transport people. Heavy accumulations of ice or snow pose risks of cables snapping. Furthermore, deposits of snow and ice that accumulate on cables and other cable system structures and break off at elevated places pose a serious risk of falling on people below and injuring them. Similar problems occur as a result of icing on towers, bridges, ship superstructures, freezers and other objects on which ice commonly forms.

SUMMARY OF THE INVENTION

The present invention helps to solve some of the problems mentioned above by providing systems and methods for de-icing of surfaces , in particular, the surfaces of cables, towers, and other components of cableway systems, such as ski lifts.

Systems and methods in accordance with the invention de-ice surfaces of components of cableway systems by melting ice in high-frequency alternating electric fields through dielectric loss heating. In certain aspects, an electrical conductor is disposed proximate to a cableway or other ski lift component to be protected against icing. A high-frequency AC voltage provided in the electrical conductor creates a high-frequency alternating electric field ("AEF") possessing capacitive AC current. The capacitive AC current (displacement current) associated with the AEF in air flows through ice on the surface of the cableway system component. A portion of the current flows through the ice capacitively, and a portion of the current flows through the ice resistively (conductively). The resistive AC current flowing through the ice generates Joule heat, which melts the ice. Thus, ice absorbs capacitive energy in the AEF, transforming it into heat that melts ice.

In certain aspects, a system for de-icing a surface of a cableway system component includes: an electrical conductor proximate to the surface; and, an AC power source for providing a high-frequency AC voltage in the electrical conductor. Preferably, the AC power source supplies power having a frequency in a range of about from 60 kHz to 100 kHz and a voltage in a range of about from 3 to 15 kV.

Numerous factors affect the dielectric loss heating of the ice. Generally, increasing voltage increases the strength of the AEF, thereby increasing the capacitive energy of the AEF. Increasing voltage increases the total current associated with the AEF. Increasing frequency also increases the total amount of AC current flowing through ice. Typically, the electrical conductor is an electrically conducting cable. An advantage of one aspect of the invention is that the electrical conductor and the cableway system component, which preferably functions as electrical ground, are disposed relatively close to each other. Typically, the electrical conductor is disposed in a range of from 0 to 30 cm from the surface of the cableway system component acting as electrical ground. Commonly, the surface of a cableway is being protected against ice and snow. In another common application of the invention, the surface of a cableway system tower is protected. Preferably, the cableway system component being protected against ice functions as an electrical sink, or electrical ground. Another aspect of the invention may include a separate electrical sink, with the surface of the cableway system component preferably located between the electrical conductor and the electrical sink. In another aspect of the invention, the electrical conductor is electrically insulated from electrical ground. In typical embodiments, therefore, in which a

cableway system component being protected serves as electrical ground, the electrical conductor is electrically insulated from the cableway system component, that is, from the cableway, cableway system tower or other component. In another aspect of the invention, two proximately-located electrical conductors are energized 180 degrees out of phase from each other, thereby generating the high-frequency alternating electric field in the ice.

A method in accordance with one aspect of the invention for de-icing a cableway system includes: applying a high-frequency high-voltage AC voltage to an electrical conductor located proximate to the surface of a cableway system component. Preferably, the AC voltage has a frequency in a range of about from 60 kHz to 100 kHz and a voltage in a range of about from 3 kV to 15 kV.

Another aspect of the invention may include a transformer to transform AC voltage having a low voltage to a higher voltage to increase the strength of the AEF. Such transformers, for example, may be located at appropriate distance intervals along the cableway system path.

Further, dielectric loss heating may be combined with skin-effect ("induction") heating at high frequency to melt ice and snow on cableways. Other aspects of the invention may include a means for frequency-tuning the high-frequency AC voltage to match the standing-wave effects of ice-dielectric heating and the skin-effect heating resulting from high-frequency current flow in a conductor. An aspect of the invention may also include a means for varying the AC frequency to change the heating pattern produced by standing wave effects of ice-dielectric heating and skin-effect heating, thereby providing sufficient heat at all locations at various times to prevent icing.

The invention is next described further in connection with preferred embodiments, and it will become apparent that various additions, subtractions, and modifications can be made by those skilled in the art without departing from the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention may be obtained by reference to the drawings, in which:

FIG. 1 depicts a system in accordance with the invention in which an electrical conductor carrying high-frequency AC voltage is disposed in close proximity to a ski lift cableway;

FIG. 2 depicts in schematic form the melting of ice on a cableway and electrical conductor

in accordance with the invention, in which the electrical conductor is excited to a high potential relative to the cableway, which functions as ground;

FIG. 3 depicts an embodiment in accordance with the invention in which the electrical conductor is stationary, being fixed at ski lift towers, and a ski lift cableway is movable;

FIG. 4 depicts an embodiment in accordance with the invention in which the electrical conductor moves together with the cableway;

FIG. 5 depicts cable hangers attached to a ski lift cableway and containing an electrically insulating sandwich in accordance with the invention;

FIG. 6 depicts in schematic form the melting of ice on an electrical conductor/cableway and on a ground cable in accordance with the invention, in which the cableway is excited to a high potential relative to the ground cable;

FIG. 7 depicts electrical conductors that are fixed proximate to a cableway system tower by electrically insulating spacers; and

FIG. 8 depicts a system in accordance with the invention in which an electrical conductor is integral with a cableway system tower and ground cables are disposed proximate to the tower;

FIG. 9 depicts in schematic form a system in accordance with the invention in which a high-frequency AC voltage is applied to a first electrical conductor and a second electrical conductor at the same AC potential from ground, but 180 degrees out of phase.

DETAILED DESCRIPTION OF THE INVENTION

The invention includes methods, systems and structures that melt ice and snow on the surface of an object by providing high-frequency AC voltage to generate an alternating electric field ("AEF") at the surface. Ice in the AEF transforms a portion of the capacitive AC current associated with the AEF into conductivity (resistive) AC current, which generates Joule heat in the ice. Although embodiments in accordance with the invention are described below principally with respect to ski lift de-icing, it is understood that the invention is useful in many types of applications.

The term "de-icing" is used in a general sense in this specification. It refers to systems and methods for removing ice and snow from cableway systems, such as ski lifts, as well as preventing the formation of significant deposits of ice and snow. In particular, it refers to melting of snow and

ice. Throughout this specification, reference is often made to "ice". The term "ice" refers generally to all forms of frozen water, including snow. Similarly, the term "cableway system", "transport system" and related terms refer principally to cableways used for support or movement of chair ski lifts, surface lifts (e.g., skis remain on the ground and are pulled forward), gondolas, aerial tramways, ropeways, funicular railways, cable cars and other cableway systems; but the terms can also refer to other structures, for example, freezers, bridges, towers, and cables supporting a bridge, tower, or tent. Generally, elongated structures de-iced in accordance with the invention are electrically conductive, such as electrically conductive, metal cableways. In some embodiments, a nonconductive structure is treated to be electrically conductive, such as through application of a conductive coating.

PCT application PCT/US00/05665, filed 1 March 2000, published as WO 00/52966, which is hereby incorporated by reference in its entirety, describes the use of high-frequency AC current to melt ice on a power line. When a lossy dielectric material, such as ice, is disposed in an AEF, AC current associated with the AEF generates heat in the material through dielectric loss. The heating power, W_h, per cubic meter of dielectric material is:

$$W_h = \frac{\omega \varepsilon \varepsilon_0}{4\pi} \tan\delta \; (\overline{E^2}) \qquad (1)$$

where ε is a relative dielectric permittivity, ε_0 is a dielectric permittivity of free space ($\varepsilon_0 = 8.85 \times 10^{-12}$ F/m), ω is an angular frequency of the AEF ($\omega = 2\pi f$, in which f is the AC frequency of the power line), $\tan\delta$ is the tangent of dielectric loss, and $(\overline{E^2})$ is the average of electric field squared. The value of the electric field, E, increases with applied voltage. At a frequency of 60 - 100 kHz, the value of ε in ice is about 3.2. For given values of ε and $\tan\delta$, an increase of frequency, f, or electric field strength, E, increases the dielectric loss heating in ice, resulting in increased heating power, W_h.

Functionally, an electrical conductor is "proximate to" a surface if an AC voltage in the conductor generates an AEF that causes sufficient dielectric loss heating in the ice to melt the ice. The term "proximate to" also refers to an electrical conductor that is integral with the cableway

system component being protected. For example, in certain embodiments in accordance with the invention, an integral part of a cableway serves as the electrical conductor. The term "proximate to" is also used to refer to distance between an electrical conductor and an electrical sink (or electrical ground). Practically, the term "proximate to" in this specification generally means within a distance of about 30 cm.

In accordance with the present invention, ice on lift cables, on lift towers or on some other structural cableway system component is melted in high-frequency alternating electric fields. The high frequency of the current flowing through the electrical conductor is generally greater than 0.5 kHz. Theoretically there is no upper limit on the frequency used. Preferably, frequencies in a range (e.g., 60 kHz to 100 kHz) similar to those used in power line de-icing are used. But due to a smaller distance between the electrical conductor and the cableway (or other component functioning as electrical ground) compared to power line systems, de-icing of cableway system components is typically accomplished with a lower voltage than that used in power-line de-icing. The strength of the AEF (E in equation (1), above) depends on several factors, in particular, on the voltage in the conductor and on the distance between the electrical conductor and electrical ground. In systems involving power transmission lines, the distance between the transmission line carrying high-frequency high-voltage current and an electrical sink functioning as electrical ground (e.g., another power line, a tower, earth) is typically several meters or more. As a result, the alternating electric field strength dissipates over a large distance. In contrast, in preferred embodiments in accordance with the present invention, the distance between the electrical conductor at maximum voltage amplitude and electrical ground is smaller, so the AEF is correspondingly stronger for a given voltage. Preferably, the distance between an electrical conductor and an electrical sink (electrical ground) is a small as possible, so long as the electrical conductor and electrical sink are not in direct electrical contact so that a strong AEF is generated. Also, the impedance to AC current flow is typically lower in a typical system for de-icing of cableway system than in power line de-icing systems. In a power transmission line system, electrical ground for the capacitive AC current associated with the AEF is typically several meters away, separated from the ice by air. In a cableway system, ice carrying capacitive current associated with an AEF typically rests on the cableway, ski tower or other component, which serves as electrical ground. As a result, the impedance encountered by the capacitive AC current is relatively low. Thus, for a given electric

field strength and AC frequency, the capacitive AC current passing through the ice increases, making more energy available for heating. For these reasons, 3 to 15 kV is typically sufficient for cableway system de-icing, instead of 30kV or more in power-line de-icing. It is clear that voltages exceeding 3-15 kV are useful in embodiments in accordance with the invention. Depending on structural dimensions and operating conditions, lower voltages, for example 500 volts, are also useful. The term "high-voltage" and related terms in the specification generally mean a voltage of 500 volts or higher.

In embodiments in accordance with the invention, the electrical conductor is electrically insulated from electrical ground. The term "electrically insulated" and related terms are used in their general sense to mean that there is no direct electronic conduction between the electrical conductor and electrical ground, which is typically a cableway, a tower or other electrically conducting cableway system component. Of course, in embodiments in which the surface being protected against icing is electrically insulated from electrical ground (or some electrical sink), the electrical conductor may be in direct physical or electrical contact with the electrically insulated surface. Also, the electrical conductor is part of a circuit including an AC power source, which inevitably includes some connection to electrical ground, but which does not prevent generation of a strong AEF between the conductor and the surface.

FIG. 1 depicts a system100 in accordance with the invention suitable for de-icing ski lift cableways. System 100 includes conventional ski lift transport system towers 102, 104, which support ski lift cableway 106 in a conventional manner. Ski lift cable 106 carries conventional ski lift chairs (not shown). System 100 further comprises electrical conductor 108, which is located proximate to ski lift cable 106. In accordance with the invention, a high-frequency high-voltage AC current flows through electrical conductor 108. In preferred embodiments in accordance with the invention, the AC current in electrical conductor 108 has a frequency in a range of from 60 kHz to 100 kHz. The high voltage generates an AEF. Preferably, ski lift cableway 106 and electrical conductor 108 are disposed at a distance in a range of from 0 to 30 cm. At this distance, a voltage in a range of from 3 to 15 kV in electrical conductor 108 is typically sufficient for melting ice.

FIG. 2 depicts in schematic form the operation of system 100 in accordance with the invention. Ski lift cableway 106 and electrical conductor 108 are covered by ice layers 110, 112, respectively, which have lossy dielectric properties. AC power source 120 is connected to

electrical conductor 108 so that a high-frequency high-voltage AC current flows through electrical conductor 108, generating an AEF 113. Ski lift cableway 106, which has a surface 107, is proximate to electrical conductor 108, preferably within a distance of 0 to 30 cm. Conventional AC power source 120 is connected to electrical ground 130. Preferably, as depicted in FIG. 2, ski lift cableway 106 (or another object having a surface being protected against the ice) is connected to electrical ground 130. This is preferred so that ski lift cableway system 106 functions as electrical ground for AEF 113 and for the AC currents in ice layers 110, 112. As depicted in FIG. 2, ice layers 110, 112 carrier resistive (conductivity) component of AC current generated by the high-frequency voltage in electrical conductor 108, the resistive AC current generating Joule heat and melting the ice.

The electrical conductor for carrying high-frequency high-voltage AC current may be made hollow, and thus may be light. The electrical conductor cable can be fixed at a distance from an electrically conducting surface being protected in a number of ways. For example, as depicted in FIG. 3, electrical conductor 308 is stationary, being fixed at the ski lift towers, and ski lift cableway 306 moves to carry a ski lift (not shown). Ski lift carrying arm 340 at distal end 339 is coupled to a ski lift chair, gondola or other person-carrying cableway system component (not shown). At proximate end 341, ski lift carrying arm 340 is attached using conventional means to electrically insulating cable hangers 342, 344. Cable hangers 342, 344 typically are manufactured with dielectric ceramic, polymer or composite material. Cable hangers 342, 344 attach ski lift arm 340 to ski lift cable 306. Connected to ski lift carrying arm 340 is an electrically insulating guiding arm 350, having a conductor clasp 352. Guiding arm 350 clasps electrical conductor 308 and essentially pushes conductor 308 away from proximate end 341 and cable hangers 342, 344 as ski lift carrying arm 340 moves in the direction of arrow 348. The electrical conductor 308 is optionally coated with an insulating material to prevent electrical contact between electrical conductor 308 and non-insulated ski lift components. Another example is depicted in FIG. 4, in which electrical conductor 408 moves together with ski lift carrying cable 406. Ski lift carrying cable 406 and electrical conductor 408 are separated from each other at a fixed distance by electrically insulating spacers 450. Cable hangers 442, 444 connect the ski lift at a fixed position on ski lift cableway 406.

Various methods and structures and may be used to insulate electrically a carrying arm and

the cableway from other, high-voltage elements of system, especially from an electrical conductor cable. For example, FIG. 5 depicts cable hangers 540,550 attached to ski lift carrying cable 506 and having an electrically insulating layer 544, 554 sandwiched between electrically conducting metal layers 542, 546 and 552, 556, respectively. The electrically insulating sandwich layers 544, 554 may contain any of a number of structurally strong electrically insulating materials, such as a ceramic insulator material.

In certain embodiments in accordance with the invention, a cableway includes an electrical conductor for generating an AEF in accordance with the invention. FIG. 6 depicts in schematic form the operation of a system 600 in accordance with the invention. Electrical conductor/cableway 607, which has a surface 605, and ground cable 609 are covered by ice layers 610, 612, respectively, which have lossy dielectric properties. High-frequency high-voltage AC power source 620 is connected to electrical conductor/cableway 607 so that the AC voltage generates AEF 613. Conventional AC power source 620 is connected to electrical ground 630. Ground cable 609 is connected to electrical ground 630. Ground cable 609 functions as electrical sink for AEF 613 and for the AC currents in ice layers 610, 612. Preferably, ground cable 609 is proximate to electrical conductor/cableway 607, that is, within a distance of 30 cm. Ice layers 610, 612 depicted in FIG. 6 carry resistive (conductivity) and capacitive AC current generated by the high-frequency voltage in electrical conductor/cableway 607. Through dielectric loss heating, the conductivity AC current generates Joule heat and melts the ice. Electrical conductor/cableway 607 is electrically insulated from other cableway system components and from ground cable 609.

A system and a method in accordance with the invention are useful for de-icing other cableway system components, such as towers. In certain embodiments, one or more electrical conductors are disposed proximate to the component being protected against ice. For example, in system 700 depicted in FIG. 7, electrical conductors 708 are fixed within a proximate distance "D" of cableway system tower 710. Electrical conductors 708 are held in place and separated from cableway system tower 710, including cableway system supporting arms 712, 714, by electrically insulating spacers 716. Electrical conductors 708 are connected to AC power source 720. Generally, cableway system tower 710 or other cableway system component having a surface being protected against ice may be either electrically conductive or nonconductive. Typically, cableway system tower 710 is conductive and is connected to electrical ground 730 via ground

cable 732, thereby functioning as an electrical sink for the AEF generated by a high-frequency voltage in electrical conductors 708. In another embodiment in accordance with the invention, a cableway system tower or other cableway system component is nonconductive and is located between electrical conductor 708 and ground cable 732 or other electrically conductive body functioning as an electrical sink. A power source 720 in accordance with the invention alternatively includes a transformer for transforming AC voltage having a low voltage to a higher voltage in accordance with the invention to increase the strength of the AEF.

FIG. 8 depicts a system 800 in accordance with the invention in which an electrical conductor is integral with cableway system tower 807 so that the cableway system tower effectively functions as the electrical conductor. Preferably, one or a plurality of electrical sinks, such as ground cables 809, are connected to electrical ground 830 and disposed proximate to electrical conductor/cableway system tower 807 and to cableway system supporting arms 812, 814. Ground cables 809 are fixed within a proximate distance "D" of electrical conductor/cableway system tower 807 and supporting arms 812, 814 by electrically insulating spacers 816. Electrical conductor/cableway system tower 807 with supporting arms 812, 814 is insulated from an electrical ground by insulator 818 and is connected to AC power source 820 via power bus 822. In another embodiments in accordance with the invention, cableway system tower 807 or other cableway system component is nonconductive or the outside surface 836 of the cableway system tower 807 or other cableway system component is nonconductive. Tower bus 822 is connected to an electrical conductor integral with cableway system component 807. A high-frequency AC voltage applied to the electrical conductor generates an alternating electromagnetic field in ice on surface 836.

In a further embodiment in accordance with the invention, skin-effect (induction) heating is used to melt ice in systems in which the electrical conductor has a length of approximately one kilometer or more. Magnetic components of an alternating electromagnetic field tend to push electrical current lines towards the surface of a conductor. In a case of high-frequency AC current flowing in 2.5 cm diameter aluminum conductor cable at 60 kHz, for example, approximately 63 percent of the current flows in the outer 0.35 mm of the conductor; approximately 95 percent flows within 1.05 mm of the outer surface of the conductor. For an electrical conductor with a diameter of 2.5 cm, this condensation of current flow into a relatively smaller cross-sectional surface area

of flow increases the overall resistance by a factor of approximately 20. With 221 amps of current, this results in a maximum heating power of approximately 50 W/m. As also described in PCT/US 00/05665, skin-effect heating may also be combined with the lossy dielectric effect to achieve de-icing. Skin-effect heating is useful in embodiments in accordance with the present invention when the spans of cableways are longer than the wavelength of the AC current. Unlike ice-dielectric heating, skin-effect heating occurs even when no ice is present. Thus, skin-effect heating prevents formation of ice on a conductor. When the high frequency AC conductor is proximate to the surface of the cableway system component being protected, the heat produced by the skin effect prevents formation of ice on the conductor, and also melts snow and ice as it deposits on the surface.

In another embodiment in accordance with the invention, an AC voltage is applied to two electrical conductors 180 degrees out of phase with each other. Either one or both of the electrical conductors may include a surface being de-iced in accordance with the invention. Either one or both of the electrical conductors may be a cableway, or may be some other object being de-iced. FIG. 9 depicts in schematic form a system 900 in accordance with the invention. First electrical conductor 908 and second electrical conductor 906 are each connected to a power terminal of AC power source 920. A ground terminal of power source 920 is connected to electrical ground 930. High-frequency AC voltage is applied to first electrical conductor 908 and second electrical conductor 906 at the same AC potential from ground, but 180 degrees out of phase with each other, corresponding to conventional sinusoidal AC voltage or to some other waveform. Preferably, first electrical conductor 908 is proximate to second electrical conductor 906 , that is, within a distance of 30 cm. One or both of electrical conductors 906, 908 may be integral with an object, such as a cableway, a cableway system component, a bridge, a ship superstructure or other conductive or nonconductive object. As depicted in schematic diagram of FIG. 9, first electrical conductor 908 is integral with an object 940 having a surface 941. Ice 950 covers a portion of surface 941. The high-frequency voltage in first electrical conductor 908 and second electrical conductor 906 generate AEF 953. Capacitive current associated with the AEF 953 flows through ice 950. Through dielectric loss heating, the portion of the AC current that flows through the ice resistively (by conduction) generates Joule heat, melting the ice.

Systems and methods in accordance with the invention typically provide heating and de-

icing of cableways and and other components while the cableway system is not in operation, for example, during the night. Embodiments of the invention are also useful while the cables and cableway system chairs are moving during normal operation. The various embodiments in accordance with the invention provide relatively simple, reliable and inexpensive systems and methods for preventing and removing ice on the surface of an object. Although the embodiments have been described principally with regard to de-icing of cableway systems, in particular, ski lifts, the structures and methods herein described are applicable to many other types of objects. For example, methods and systems in accordance with the invention are useful for de-icing surfaces of bridges, ships, and steel towers. It is evident that those skilled in the art may now make numerous uses and modifications of the specific embodiments described, without departing from the inventive concepts. It is also evident that the steps recited may, in some instances, be performed in a different order; or equivalent structures and processes may be substituted for the structures and processes described. Since certain changes may be made in the above apparatus and methods without departing from the scope of the invention, it is intended that all subject matter contained in the above description or shown in the accompanying drawing be interpreted as illustrative and not in a limiting sense. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in and/or possessed by the systems, methods and compositions described.